# SCIENCE FOR GLASS PRODUCTION

## PROMPT CALCULATION AND CORRECTION OF THE GLASS BATCH FORMULA

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A new program for the calculation of a glass batch formula has been developed that accelerates and improves the calculation process, makes it possible to simulate the variation of the glass composition with the chemical composition and ratio of raw materials, and quickly perform multiple recalculations of different variants.

The service properties of float glass depend on the homogeneity of the glass melt, which, in turn, depends on the quality of raw materials and the methods of material treatment and batch preparation. The advisability of using a material from a particular deposit is determined not only by the state of available resources and the cost of fuel and labor consumed in processing, but mostly by the stability of the chemical composition.

The production of light-shielding bulk-tinted glass on an ÉPKS-4000 production line at the Saratov Institute of Glass for 6 years was based on sand from the Aleksandrovskoe deposit (Saratov Region) with an unstable elevated content of calcium and magnesium oxides and, which is especially significant, of aluminum and iron oxides varying from 0.27 to 0.65%, as well as soda produced from a nepheline material with an unstable elevated content of $K_2SO_4$.

The presence of colorant sulfurous iron compounds and iron and titanium oxides in the materials, as well as their ratio in the finished glass, have a significant effect of the formation of tint and light-shielding properties.

Industrial practice shows that melting bulk-tinted glass frequently causes problems due to fluctuations in the content of iron oxide, inappropriate dosing of the iron-containing component, and its nonuniform distribution in the batch. This causes modifications in the enthalpy of the glass melt layers and in glass tinting, increases the tendency for cord formation, and may produce a mobile silica film. Stabilizing the iron oxide content in a glass melt is a very urgent problem when using sand of heterogeneous chemical composition.

The prescribed stable ratio between bivalent and trivalent iron in a light-shielding glass is accomplished by introducing

sulfate and sodium nitrate (saltpeter), whose content is determined as well by the quantity of the colorant additives (selenium and cobalt). Thus, in calculating a batch formula for tinted glass, it is important to promptly correct not only the content of the main components but also the ratios between sulfate, saltpeter, and soda.

A method for correcting the composition of a glass batch based on standard sand [1] to stabilize the iron oxide content in glass recommends modifying the formula not more often than once every three weeks by means of introducing the iron-oxide pigment or crocus. In this case the fluctuations of the $Fe_2O_3$ content in glass usually do not exceed 0.01%.

The authors of [2] calculated an optimum batch formula to stabilize the glass melt composition, taking into account admissible deviations in the content of oxides in glass. The maximum admissible deviations for individual oxides are calculated based on glass density data, whose stability is one of the indicators of the quality of glass-melting and of correcting the batch composition. It is established that fluctuations of the content of oxides in the glass should not exceed 0.005% for $Fe_2O_3$ and 0.1% for $Al_2O_3$.

Since the fluctuations of the iron oxide content in standard sand are insignificant, i.e., not more than 0.005% with the total $Fe_2O_3$ content equal to 0.02 – 0.10%, the increment in the deviations from a prescribed composition is slow. Substandard sands show a different picture: the fluctuations in the content of iron and aluminum oxide in different deliveries of sand from the Aleksandrovskoe deposit to the warehouse of the Saratov Institute of Glass reached 0.3 – 0.5%, respectively.

Using an analysis of the bronze-colored glass produced on the float line, we constructed a diagram reflecting the de-

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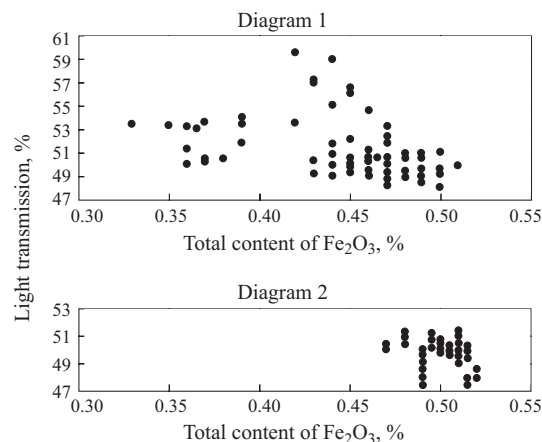
**Fig. 1.** Light transmission in the visible spectrum region as a function of iron oxide content refered to $Fe_2O_3$ prior to (diargram 1) and after (diagram 2) introduction of iron powder.

pendence of the light transmission in the visible spectrum range on the total content of iron oxide in the glass converted to $Fe_2O_3$ (Fig. 1). Diagram 1 corresponds to the period when the batch was prepared without corrective iron-bearing additives, i.e., it reflects the amount of iron oxide introduced with the material. According to diagram 1, the total content of iron oxide in glass varies within the limits of $0.35 - 0.51\%$, mainly from 0.45 to 0.48% $Fe_2O_3$. The light transmission of glass in the visible spectrum range varies from 47.5 to 59.5%. Such significant fluctuations are not admissible. To produce light-and heat-shielding glass with low transmission in the visible spectrum (49 – 52%) based on the substandard Alexandrovskoe sand, it was decided to add iron powder to reach a preset optimum content of iron oxide in the glass equal to 0.48 – 0.50%.

The technological control laboratory of the Saratov Institute of Glass developed a method for correcting the batch composition by means of iron powder additives, which makes it possible to maintain the chemical composition and the light transmission of light- and heat-shielding glass within prescribed limits. A calculation of the amount of additives takes into account the total content of iron oxide in glass and in sand and the batch : cullet ratio. A correction is performed when the light transmission in the visible range changes by more than $0.3 - 0.4\%$ taking into account the light transmission in the IR range and the $Fe_2O_3$ : FeO ratio in the glass.

**Example of a calculation of the amount of an iron powder additive for a batch portion intended for 100 kg of glass melt.**

*Data for calculation:*

The calculation for correcting the batch formula regarding the $Fe_2O_3$ content is carried out taking into account a

100% content of iron in the powder; the conversion coefficient (%):

$$Fe_2O_3 = Fe \times 1.429;$$

the chemical analysis of glass for the content of $Fe_2O_{3\ tot}$ — 0.425%;
the chemical analysis of sand from the weighing line: 0.347% $Fe_2O_3$;
the estimated data from the oxide balance based on the amount of $Fe_2O_3$ introduced by the rest of the materials 0.03%;
the batch : cullet ratio is 70 : 30%;
the weight of sand per 100 kg of glass melt is 74.3 kg;
a preset quantity of $Fe_2O_3$ in glass is 0.45%.

*Calculation:*

$Fe_2O_3$ introduced into the glass-melting furnace via the batch and the cullet:

$$0.03 + (0.347 \times 0.743) \times 0.7 + 0.425 \times 0.3 = 0.3289\%;$$

the deficit of $Fe_2O_3$ for this composition of batch and cullet is:

$$0.45 - 0.3289 = 0.1211\%;$$

taking into account the batch : cullet ratio:

$$0.1211 : 0.7 = 0.173;$$

in order to obtain this quantity of $Fe_2O_3$, it is necessary to introduce the following quantity of iron powder for a batch required for 100 kg of glass melt:

$$0.173 : 1.429 = 0.1210 \text{ kg of iron.}$$

*Verification:*

$$(0.425 \times 0.3) + (0.347 \times 0.743 + 0.173 + 0.03) \times 0.7 = 0.450\% \ Fe_2O_3.$$

As the result of using this method for correcting the batch formula, the fluctuations in the composition and the light transmission of glass produced at the Saratov Institute of Glass decreased. Diagram 2 (Fig. 1) reflects a decreased spread in the light transmission values in the visible spectrum range and the total content of iron oxide, at the same time the process of formation of glass properties became more controllable.

The Saratov Institute of Glass also developed a computer program for the calculation of the basic glass batch formula. The program is written in Microsoft Excel 2000 with applications in Visual Basic, which makes it possible to accelerate and upgrade the calculation process, to simulate the modifications in the glass composition depending on changes in the chemical composition of raw materials, and to perform a

prompt calculation of different variants involving new materials. For the convenience of the user, the following data are presented as an integrated table:

– composition of raw materials;

– a preset chemical composition of glass;

– percent content of oxides introduced with different material components;

– a theoretical batch composition;

– consumption of materials for different batch portions;

– percent ratio of alkaline oxides introduced with soda, sulfate, and saltpeter, and soda consumption taking into account dispersion;

– balance of oxides.

The implementation in 2000 of this computer program on the ÉPKS-4000 production line for the calculation of a glass batch for light- and heat-shielding glass with a non-traditional set and ratio of raw materials made it possible to stabilize the chemical composition of the batch and the glass melt. A higher accuracy and promptness of corrective measures was reached, which improved the main quality parameters of the resulting batch and the specific technological parameters of glass. An advantage of this program is the possibility of rapid multiple recalculations of different combinations of new materials, enabling one to assess and select material suppliers in compliance with international quality requirements.

The use of the program for the calculation of the glass batch formula together with the developed method of prediction, calculation [3], and control of light-engineering characteristics of glass by introducing metallic pigments and oxidizers into the batch made it possible to stabilize the quality parameters of glass. The practice of the float-glass line at the Saratov Institute of Glass indicates that refining the methods for correcting the batch composition helps to intensify the production processes, expand the product range, and raise the product quality.

**REFERENCES**

1. N. A. Pankova, L. Ya. Levitin, I. V. Aleksandrova, and I. N. Gorina, "Methods for stabilization of the iron oxide content in glass," *Steklo Keram.*, No. 1, 4 (1980).
2. Yu. L. Spirin, S. N. Dedyukov, and E. M. Zolotnik, "Calculation of the optimum batch composition," *Steklo Keram.*, No. 11, 6 (1981).
3. N. N. Shcherbakova, V. I. Kondrashov, I. A. Kupriyanova, and V. A. Gorokhovskii, "Regression equation for determining light transmission in bulk-tinted float glass," *Steklo Keram.*, No. 5, 10 – 11 (2001).